

Integrated Pest Management of Sweetpotato in the Caribbean

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Abstract

Insect pests of sweetpotato are best controlled by integrated pest management (IPM) approaches. The sweetpotato weevil, *Cylas formicarius*, is the most important worldwide pest, however in some Caribbean nations, the West Indian sweetpotato weevil, *Euscepes postfasciatus*, is the predominant species. Wireworms, cucumber beetles, white grubs, flea beetles, and various foliar pests also may occur. An emerging pest in Jamaica is the sweetpotato leaf beetle. A sweetpotato IPM program, developed under IPM CRSP (Collaborative Research Support Program) and tested in Jamaica, demonstrated a 2-3-fold reduction in pest damage. This program emphasized cultural control techniques, such as good land preparation, irrigation, drainage, crop rotation, field sanitation, selection of clean cuttings, and prevention of root exposure by hilling plants and keeping the soil moist to prevent cracking. Harvest should be prompt, and piecemeal harvesting is discouraged. Old plant materials and alternate hosts should be destroyed. Various biological control measures, like pheromone traps for weevil monitoring and control, can be used. If available, resistant varieties should be planted. Insecticides should be used only when necessary. The development, evaluation, and implementation of an IPM program should involve a baseline survey, technology transfer, and impact assessment phases. Pest problems vary from island to island in the Caribbean, so regionalization of IPM technology should be tailored to meet special local needs. Differences in regional tastes and production practices, policy issues, regulatory considerations, and economics must also be considered. IPM implementation depends on efficient distribution of information using books, information bulletins, fact sheets, and internet services. Demonstration plots and farmer-participatory workshops are useful.

INTRODUCTION.

Sweetpotato, *Ipomoea batatas* (L.) Lam., is one of the most important food crops in developing countries, where over 95% of the world's production occurs (CIP, 1996; Hijmans et al., 2001). In developing countries, including much of the Caribbean basin, sweetpotato is a major staple crop that offers food security during times of famine (Horton, 1988). Although sweetpotatoes are mostly grown for human consumption, they are also used for animal feed, for starch extraction, and for the production of ethanol (CIP, 1999).

Insect pests rank as one of the top three production problems for sweetpotatoes worldwide (Horton and Ewell, 1991). Several soil insect pests attack this crop in the Western Hemisphere (Edward, 1930; Fennah, 1947; Cuthbert, 1967; Hill, 1983; Schalk and Jones, 1985; Chalfant et al., 1990; Jansson and Raman, 1991). The sweetpotato weevil, *Cylas formicarius* (Summers), is by far the most important pest species on sweetpotato in the Caribbean (Lawrence et al. 1997). In fact, *Cylas* spp. are the number one pest problem of sweetpotato production in the world (Jansson and Raman, 1991). They attack sweetpotato stems and storage roots, both in the field and in storage facilities. Weevils may cause devastating losses, and in some documented

cases they have destroyed the entire crop. However, in some Caribbean nations, the West Indian sweetpotato weevil (“scarabee”), *Euscepes postfasciatus* (Fairmaire), is the predominant weevil species (Raman and Alleyne, 1991). An emerging pest in Jamaica is the sweetpotato leaf beetle, *Typophorus viridicyaneus* Crotch (Jackson et al., 1999; Lawrence et al., 1997, 1998, 1999b, 2000, 2001), which has also been described in the United States (Brannon, 1938). A WDS (Wireworm-*Diabrotica*-*Systema*) complex (Schalk et al., 1991) was originally defined in the United States, but a similar damage complex occurs in the Caribbean (Lawrence et al., 1999b, 2000, 2001). Wireworms, *Conoderus falli* (Lane), *C. vespertinus* (F.), and *C. amplicollis* (Gyllenhal); cucumber beetles, *Diabrotica balteata* (LeConte) and *D. undecimpunctata howardi* (Barber); and white grubs *Phyllophaga* spp. and *Plectris aliena* (Chapin), are important in the USA (Cuthbert, 1967). Other important soil pests are whitefringed beetles, *Graphognathus* spp.; the sweetpotato flea beetle, *Chaetocnema confinis* (Crotch); the elongate flea beetle, *Systema elongata* (F.); and *Phyllotreta* spp. (Cuthbert, 1967; Schalk and Jones, 1985; Chalfant et al., 1990). Various foliar pests have also been described. These include the sweetpotato hornworm, *Agrius cingulata* (F.); sweetpotato vine borer, *Megastes grandalis* Guenée; sweetpotato leafminer, *Bedellia orchilella* (Walsingham); sweetpotato whitefly, *Bemisia tabaci* (Gennadius); golden tortoise beetle, *Metritona bicolor* (F.); and lace bugs (Tingidae) (Fennah, 1947; Cuthbert, 1967; Hill, 1983; Schalk and Jones, 1985; Chalfant et al. 1990).

Insect pest populations can best be reduced through integrated pest management (IPM) approaches (Jansson and Raman, 1991). IPM for sweetpotato is not a new concept, and many of the cultural practices that are the backbone of most sweetpotato IPM programs have been advocated for years (Chittenden, 1919; Reinhard, 1923; Smith, 1960; Sutherland, 1986; Sorensen, 1987; Talekar, 1983; 1987b, 1988, 1991; Chalfant et al., 1990; Jansson and Raman, 1991; Smit, 1997a). In fact, some IPM components have been known for over 300 years in Jamaica (Fielding and Van Crowder, 1995).

However, comprehensive IPM approaches on a large scale are relatively new. Recently, CIP-sponsored sweetpotato IPM programs have been described from Cuba (Alcázar et al. 1997; Morales-Tejon et al., 1998; Lagnaoui et al., 2000; Maza et al., 2000), Haiti, and the Dominican Republic (Alvarez et al., 1996). These IPM programs are quite similar to the IPM-CRSP (Integrated Pest Management-Collaborative Research Support Program) program developed by us in Jamaica (Lawrence et al., 1997; Lawrence, 1999). However, the Cuban model relies more on pest-resistant or tolerant varieties (short-season types and cultivars with deep root formation) and biological control agents (fungal pathogens and predators). Both the Jamaican and Cuban IPM programs reported 2-3-fold reductions in pest damage over conventional techniques (Alcázar et al., 1997; Lawrence et al., 1997, 1998, 1999b, 2000, 2001; Maza et al., 2000). Other sweetpotato IPM efforts have been reported for eastern Africa (Smit and Odongo, 1997), Taiwan (Talekar, 1988), Okinawa (Yasuda, 2000), Indonesia (Braun, 1999), India (Pillai et al., 1993), and the Philippines (Amalin et al., 1991; Batalon and Escano, 2000).

In this study, we investigated the development and implementation of insect control measures for use in sweetpotato IPM programs in the Caribbean. The basic components of the Caribbean sweetpotato IPM program described herein were developed over the past 8 years under the USAID-funded IPM-CRSP project “Integrated Pest Management (IPM) of Major Pests Affecting Sweetpotato in the Caribbean” (Lawrence et al., 1997, 1998, 1999a, 1999b, 2000, 2001; Jackson et al., 1999; Jackson, 2000). Objectives of this project included: (1) Evaluation of resistant varieties and biorationals (insect growth regulators, entomopathogenic nematodes, fungi, and bacteria) for managing sweetpotato weevil, sweetpotato leaf beetle, and other soil insect pests; (2) evaluation of the potential of dry-flesh USDA, Jamaican, and OECS pest-resistant lines under Caribbean growing conditions; and (3) regionalization of sweetpotato IPM technology within selected countries of the Caribbean through demonstration and training (Tolin et al., 2001). IPM for the Caribbean was recently defined as “a sustainable pest management strategy that

emphasizes a farmer participatory approach in selecting and integrating environmentally compatible tactics to reduce pest damage below an economic threshold in mono- and multi-cropping systems of the region in order to market internationally competitive products” (McDonald and Lawrence, 1999). This definition includes considerations of economics, social issues, and policy decisions, but farmer participation is the focal point. The importance of the farmer participatory approach for ecological crop management in the Caribbean has been emphasized (Kairo et al., 2000).

MATERIALS AND METHODS

We tested seven types of pheromone-baited (Heath et al., 1991) traps for monitoring sweetpotato weevils at the U. S. Vegetable Laboratory (USVL). The trap types were: (1) a modification of the standard funnel trap (Proshold et al., 1986), (2) an adaptation of a trap described by Talekar (1988), (3) a yellow-and-white universal trap (Pest Management Supply Company [PMSC], Hadley, MA), (4) a commercial plastic *Diabrotica* trap (Trece, Salinas, CA), (5) a Japanese beetle trap (PMSC, Hadley, MA), (6) a milk-jug trap (Alvarez et al., 1996; Lawrence and Myers, 1999), and (7) a prototype of a trap made from a 5-gallon plastic bucket that was first observed by the first author (DMJ) in a farmer’s field in Antigua in 2000. One trap of each type was placed in each of two sweetpotato fields. Traps were checked twice weekly from 12 June to 31 Dec., 2001. After each trap was checked for weevils, it was rotated one position in the field so that over the season each trap occupied each field position several times. Pheromone lures were changed every 6 weeks.

As part of a long-term breeding program (Jones et al., 1986) we are developing dry-fleshed sweetpotato clones for use in value-added products (chips and fries), as a replacement for current Boniato types in south Florida, and for use in IPM programs in the Caribbean. Over the last five years we have evaluated over 120 advanced dry-fleshed breeding lines in replicated plots in South Carolina, using published evaluation techniques (Schalk et al. 1991). Seventy promising lines from our breeding program have been grown in replicated plots in the Caribbean (Jamaica and St. Kitts) over the past 8 years (Lawrence et al., 1998, 1999a, 1999b, 2000, 2001; Jackson et al., 1999; Bohac et al., 2001). We also grew one potential Boniato-type (W-341) and two commercial Boniato varieties (‘Picadito’ and ‘Homestead’) in replicated (5) plots near Homestead, Florida in 2001. These plots were planted on 11 May and harvested on 25 September, 2001. Ten roots from each plot were evaluated for yield and for insect and nematode damage.

RESULTS

In our study, pheromone-baited traps were quite useful for monitoring weevil populations in our fields over the season (Fig. 1). The standard funnel trap (1052 weevils) and the adaptation of the Talekar (1988) trap (1046 weevils) were most efficient at capturing sweetpotato weevils at the USVL in 2001 (Fig. 2). Interestingly, the 5-gallon bucket prototype (715 weevils) captured over twice as many insects as the universal trap (290 weevils) or the milk-jug trap (213 weevils), which is currently recommended (Lawrence and Myers, 1999). Neither the Trece trap (90 weevils) nor the Japanese beetle trap (50 weevils) were effective (Fig. 2).

The sweetpotato breeding program at the USVL has been very successful in developing orange-fleshed breeding lines and varieties with multiple resistance to insects and diseases (Jones et al., 1986; Schalk et al., 1991, Collins et al., 1991). More recently, we have developed several dry-fleshed types with excellent resistance to WDS and moderate resistance to sweetpotato weevil (Table 1) (Jackson et al., 1999, Bohac et al., 2001). One promising Boniato type (W-341) showed fair resistance to WDS and sweetpotato weevil, and very high resistance to root knot nematodes (Fig. 3).

DISCUSSION

Pesticide abuse is an increasing problem in the Caribbean, and it can have negative impacts on family income, farmer and farm worker health, consumer health,

water quality, and the environment that can impact tourism, the region's key economic resource (Kairo et al., 2000). There is a clear and urgent need to develop and implement integrated pest/crop management systems in the Caribbean (Kairo et al., 2000). Despite recent IPM successes in the region (Lagnaoui et al., 2000; Lawrence et al., 1997), farmers still rely heavily on synthetic pesticides to address sweetpotato pest problems. It should be noted that insecticides can be an integral part of any IPM program, however they should be used carefully and judiciously. Not only are insecticides expensive, but they may also disrupt the natural biological control forces that keep secondary pests in check (Jansson and Raman, 1991).

Sweetpotato IPM is heavily dependent on sound cultural control techniques (Reinhard, 1923; Talekar 1983, 1987b, 1988; Sutherland, 1986; Smit, 1997a; Anonymous, 2001). Field site selection is important, and such factors as soil type, irrigation potential, and drainage should be considered. Growers are advised to rotate crops and avoid continuous production of sweetpotatoes in the same field. Good land preparation and field sanitation are essential. Growers should destroy old fields and bury or burn all contaminated roots and vines. Alternate weed hosts should be identified and destroyed if possible. However, removal of wild host plants may not be practical or advisable in Caribbean nations that are heavily dependent on tourism (Anonymous, 2001). Establishment of a healthy, pest-free field is important. Growers should start with clean cuttings without roots. Cuttings should be taken from the terminal 25-50 cm of the vines where weevil eggs are not likely to occur (Talekar, 1988, 1991). Cuttings should be spaced properly, planted deeply, and watered for prompt establishment. During the growing season, soil should be hilled around the plants so that roots are not exposed. Soil should be kept damp so that it does not crack, as cracks allow access to the roots by weevils (O'Hair, 1991). In some circumstances, foliar pests can be controlled through hand picking. Mature sweetpotato roots should be harvested promptly. In general, piecemeal harvesting practices are discouraged, although Smit (1997b) showed that the impact of this practice may not be as detrimental to overall yield as once thought. Immediately after harvest, old plants and roots should be destroyed. In-ground storage is not recommended. Above-ground storage facilities should be kept clean of pests, and infested roots should be removed and burned or buried.

One key to any IPM program is good pest detection. Growers should carefully examine their plants and they should occasionally dig growing roots to monitor pest infestations and to properly time harvesting. Pheromone-baited traps have been shown to be useful for monitoring male sweetpotato weevils (*C. formicarius* only) or for population suppression (Talekar, 1991; Heath et al., 1991; Jansson et al., 1991a; Hwang and Hung, 1991; Pillai et al., 1993; Yasuda, 1995; Alvarez et al., 1996; Alcázar et al., 1997; Smit et al., 1997, 2001; Li, 1998; Braun, 1999; Jenn-Sheng, 2000). At least 1-2 pheromone traps should be located within each hectare of sweetpotatoes (Lawrence, 1999). Several authors have reported that the standard funnel trap is the most effective at capturing male sweetpotato weevils (Jansson et al., 1991a, 1991b; Yasuda et al., 1992; Smit et al., 1997), but this trap is bulky, expensive, and not well suited for growers in the Caribbean (Jansson et al., 1991a). Because cost of the pheromone lure is significant to sweetpotato growers in developing countries (Jansson et al., 1991a), it would be best to optimize the usefulness of each lure. Although the currently recommended bottle trap (Alvarez et al., 1996; Lawrence and Meyers, 1999) is inexpensive, it is much less effective than other designs (Fig. 2). We are encouraged by the trap results from the 5-gallon bucket trap. It is relatively inexpensive, mobile, and easy to maintain because the water does not have to be changed as often as in smaller traps. This trap also sits directly on the ground, which could improve trap captures. Sweetpotato weevils have limited flight activities (Reinhard, 1923), and Yasuda et al. (1992) observed that most male weevils approached pheromone-baited traps by walking, so traps placed on the ground captured more insects than those suspended in the air.

Various biological control measures may also be employed as part of the sweetpotato IPM program. Natural biological control agents should be conserved through judicious use of pesticides that may be toxic to beneficial organisms (Jansson,

1991). Predatory ants, nematodes, and entomopathogens (especially, *Beauveria bassiana* [Bals.] Vuill. and *Metarrhizium anisopliae* (Metschnikoff) Sorokin) may be effective against weevils (Su et al., 1988; Jansson, 1991; Alcázar et al., 1997; Yasuda, 2000). Biological and biorational spray materials (pepper spray and garlic juice) have been evaluated as part of the IPM CRSP research (Lawrence et al., 1998, 1999b, 2000, 2001).

Growers should plant resistant or less-susceptible varieties when they become available (Anonymous, NDG; Lawrence, 1999). Such pseudoresistance mechanisms as short-season or deep-rooted types have been shown to be useful in sweetpotato IPM programs (Morales-Tejon et al., 1998; Lagnaoui et al., 2000), but these sweetpotato cultivars may have lower root yields, lower dry matter, or they can add to harvesting difficulties. Several multiple-pest resistant sweetpotato cultivars and breeding lines have been released by the USDA program (Schalk et al., 1991; Collins et al., 1991, 1999; USDA, 1999; Bohac et al., 2000, 2001). Development of weevil-resistant cultivars may be difficult due to variability in insect infestations or interactions with environmental factors (Talekar, 1987a; Collins and Mendoza, 1991), but because of recent successes in breeding and evaluating weevil resistance (Thompson et al., 1999; Jackson et al., 1999; Lawrence et al., 1999a, Table 1, Fig. 3), we are optimistic that acceptable weevil-resistant cultivars can be developed. However, it will require the same concerted breeding effort and years of dedicated teamwork that was needed to develop resistance to WDS (Jones et al., 1986; Schalk et al., 1991). Promising pest-resistant, dry-fleshed types (Table 1, Fig. 3) (Jackson et al., 1999, Bohac et al., 2001) will be a welcome addition to IPM programs in the Caribbean.

The development, evaluation, and implementation of an IPM program to a new geographic location should involve a baseline survey, technology transfer, and impact assessment phases (Lawrence et al., 1999b). Differences in regional tastes and production practices, policy issues, regulatory considerations, and economics must also be considered (McDonald and Lawrence, 1999). Pest problems vary from island to island in the Caribbean. For example, *C. formicarius* is the predominant weevil pest throughout much of the Caribbean basin. However, in some locations, such as St. Lucia, both *C. formicarius* and *E. postfasciatus* are present, and in other locations, such as St. Vincent, only *E. postfasciatus* is found (Anonymous 2001). Occasionally, insects other than weevils are the major pest species in the Caribbean. For example, the sweetpotato leaf beetle, *T. viridicyaneus*, has recently emerged as a predominant pest species in certain parishes in Jamaica. Other pests, such as *Megastes* sp. in Trinidad and a lace bug in St. Lucia have recently been cited as difficult to control (Jansson and Raman, 1991). Therefore, regionalization of IPM technology throughout the Caribbean should be tailored to the special needs of a particular location. The necessity of a thorough baseline survey cannot be over-emphasized. An effective IPM program should also fit into an overall Integrated Crop Management (ICM) system for sweetpotato, which has been shown to lead to increased net income for farmers (Van de Fliert et al., 2001).

The implementation of sweetpotato IPM throughout the Caribbean (i.e., regionalization) depends on the efficient distribution of information describing this technology. Such tools as books, information bulletins (Talekar, 1988; Morales-Tejon et al., 1998), fact sheets (Lawrence, 1999; Lawrence and Meyers, 1999; Anonymous, NDG), and internet services are integral to information distribution. Demonstration plots of new techniques or research can also be informative, but perhaps the most useful technique for dissemination of IPM technology is through the training of growers using the Farmer Field School (FFS) approach (Braun et al., 1997). This farmer participatory approach has been quite successful in the regionalization of sweetpotato IPM in the Caribbean (Kairo et al., 2000).

Regional expertise needs include biological studies of key pest species; pest risk analyses; development of information systems to enhance regional communication in IPM; development of Geographical Information System (GIS) applications for IPM; and training of experts to implement and maintain IPM programs. Future research needs include development of dry-fleshed, multiple

pest-resistant varieties; evaluation of new insecticides; and evaluation of biological and biorational materials for pest control.

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Tables

Table 1. Physical characteristics and insect ratings for selected dry-fleshed sweetpotato breeding lines or cultivars grown in Charleston, South Carolina, USA, 1997-2001.

Sweetpotato Entry	Skin Color	Flesh Color	Average WDS Index ^a	% Clean ^b Roots	% Weevil- ^c Infested Roots	Average ^d Weight per plot (kg)
PI 399163 ^e	Purple	Purple	0.124	59.7	3.0	2.7
95-161 ^f	Tan	Medium Yellow	0.150	73.9	0.0	10.5
96-86 ^f	Medium Copper	Orange	0.194	73.1	1.1	3.8
W-326 ^f	Rose	Yellow	0.201	47.1	1.4	4.4
95-102 ^f	Red	Light Orange	0.201	23.8	1.8	4.4
TIS 2498 ^e	White	White/Purple ^h	0.207	58.4	0.7	4.2
97-88 ^f	Red	Light Orange	0.213	69.1	0.5	3.7
95-190 ^f	Light Copper	Cream	0.224	35.4	1.9	5.2
Tapato ^e	Dark Rose	Light Yellow	0.226	62.6	1.0	8.8
Tanzania ^e	White	White	0.233	56.9	4.6	3.6
Tinian ^e	Purple	White	0.237	50.5	0.6	3.1
94-127 ^f	Rose	Yellow	0.248	57.5	0.3	12.4
97-95 ^f	Red	Medium Yellow	0.277	69.3	0.4	18.6
94-145 ^f	Rose	Light Yellow	0.280	58.0	0.2	13.3
Sumor ^{fg}	Tan	Cream	0.304	52.6	0.8	23.2
97-94 ^f	Red	Light Yellow	0.308	67.0	0.0	13.0
White Regal ^{fg}	Scarlet	Cream	0.357	55.4	1.8	14.2
W-341 ^f	Red	Cream	0.391	55.8	1.9	13.0
PI 538288 ^e	Purple	White	0.419	35.9	---	7.6
Minamiyutaka ^e	Tan	White	0.421	35.3	2.8	24.9
95-175 ^f	Red	Light Yellow	0.434	36.7	1.1	17.8
Picadito ^{eg}	Scarlet	White	0.452	45.9	2.4	12.8
96-47 ^f	Red	Yellow	0.452	42.2	0.2	9.5
W-308 ^f	Light Copper	Yellow	0.521	39.3	0.0	22.6
97-82 ^f	Red	Yellow	0.531	49.7	---	15.2
W-364 ^f	Purple	White	0.598	47.0	3.8	16.9
HiDry ^f	White	White	0.638	29.0	---	10.5
Beauregard ^g	Dark Copper Rose	Orange	1.155	27.0	8.8	24.4
SC 1149-19 ^f	Light Copper	Light Orange	1.524	17.4	12.9	18.3

^aWireworm-*Diabrotica-Systema* complex (WDS). Score based on the number of feeding scars (0 = no scars, 1 = 1-5 scars, 2 = 6-10 scars, 4 = more than 10 scars).

^bIncludes damage by WDS, flea beetles, white grubs, and sweetpotato weevils.

^c2001 data only.

^dFor 10-plant plots.

^ePlant Introduction from USDA-ARS collection at Griffin, GA.

^fBreeding line or cultivar from the sweetpotato breeding program at the U. S. Vegetable Laboratory, Charleston, SC.

^gCommercial sweetpotato cultivar grown in the USA.

^hWhite flesh with purple flecks.

Figures

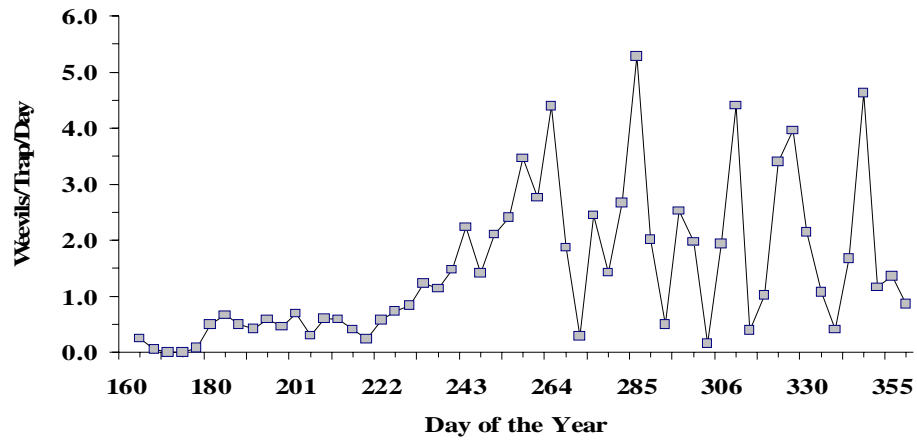


Fig. 1. Captures of adult male sweetpotato weevils in pheromone-baited traps in Charleston, SC, 2001.

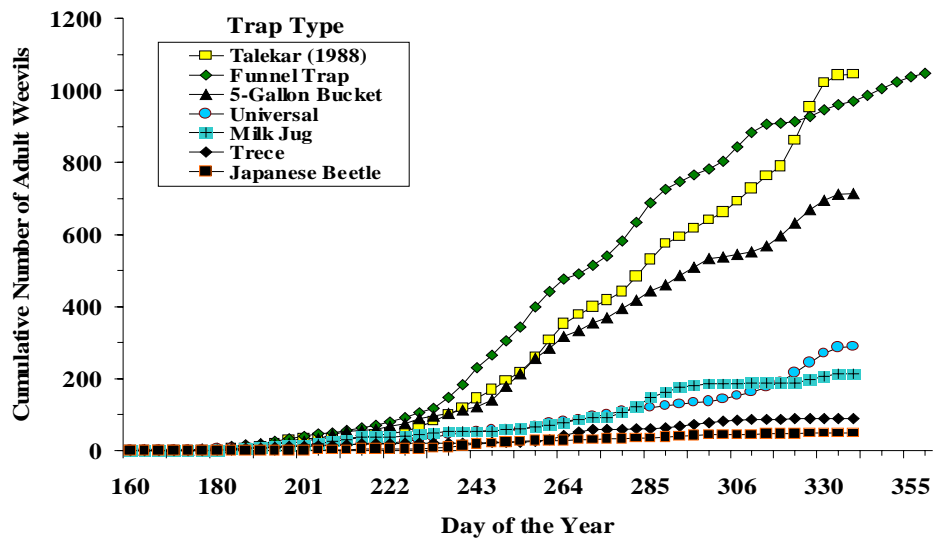


Fig. 2. Cumulative captures of adult male sweetpotato weevils in seven types of pheromone-baited traps in Charleston, SC, 2001.

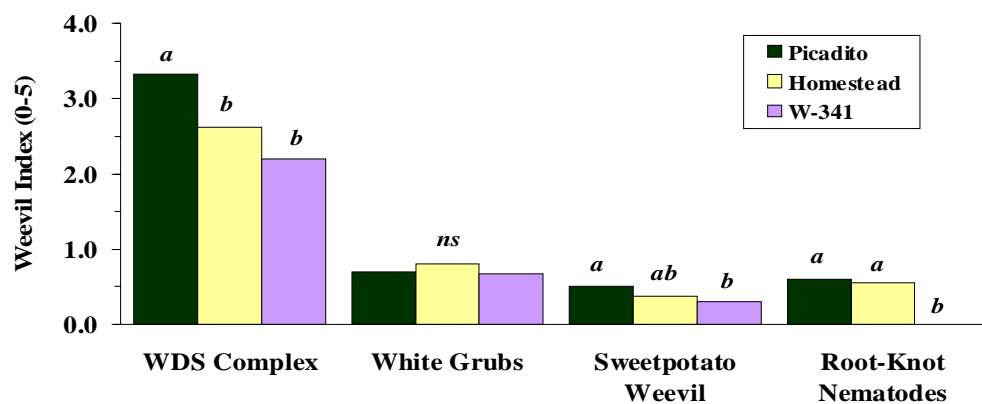


Fig. 3. Resistance of a USDA-ARS sweetpotato advanced breeding line (W-341) to insect and nematode pests in Homestead, Fla., 2001. Means for each pest followed by a common letter are not significantly different ($P=0.05$, DMRT).